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Prospective scenarios for the biodiesel chain of a Brazilian state

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ABSTRACT

This paper presents a study based on the Systems Thinking and Scenario Planning (STSP) method, focusing the biodiesel production chain of Rio Grande do Sul State. The aim of the study was to identify key elements to comprehend the systemic structure of interaction among the ties of this chain. The study was held by a team of specialists over five months, including 15 meetings. Discussions were based on quantitative and qualitative data and a systemic map was constructed and refined. Based on this modeling, four different prospective scenarios were comparatively analyzed in order to propose strategic actions to promote the sustainability and competitiveness of the chain. The results were then presented to two different groups of external specialists in order to validate the conclusions drawn and the proposals. Both groups agreed with the ideas presented. The paper is constructed as follows: a brief introduction focusing on contextual elements of the biodiesel production in Brazil and in Rio Grande do Sul; some background material regarding agroindustrial production chains and an overview of the biodiesel production chain of interest; a description of the method used to perform the research; main results and discussion; and conclusions. With this paper the authors also hope to contribute to the discussion regarding competitiveness and sustainability of biofuel chains in Brazil.

Contents

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1. Introduction

Biodiesel production is a strategic theme for technology and innovation research in Brazil. It has gained prominence since the start of the National Program for Production and Use of Biodiesel (PNPB), in 2005. The aim of this program is to introduce and sustain the use of this renewable source of energy on Brazil's energetic matrix. In order to do so, PNPB has three main goals: (i) to regulate the operation of the biodiesel market in Brazil, by establishing mandatory percentages of this biofuel on diesel (and, by this way, determining the national demand for biodiesel); (ii) to encourage the diversification of raw materials for the production of biodiesel in all regions of the country; (iii) to incorporate small (family) farms to the biodiesel production chain.

In Brazil, biodiesel for commercial purposes is mainly produced from soybean, rapeseed, sunflower, canola and castor crops. There is also a small percentage of production from animal fat and used cooking oil. One of the major interests of Brazil's Federal Government (FG) on promoting the research and production of biodiesel is to reduce the national dependency of petroleum and its supply chain. Accordingly to estimates of the Brazilian National Petroleum Agency (ANP), reduction in imports of diesel will result in savings of about USD$ 410 million per year and generate foreign currency for the country, besides the dependency of petroleum would be reduced in 5–7% (ANP [2]). Other goals involve reducing environmental pollution and generating alternative employment in areas less attractive to other economic activities, thereby, promoting social inclusion (BRASIL [30]).

In January 2008, PNPB stated the adoption, in Brazil, of 2% blend of biodiesel in diesel (B2). Driven by the possibility of future opportunities, the expansion of the production sector of biodiesel was overly anticipated, causing idleness on most of the plants. As a consequence, nowadays the installed capacity is sufficient to meet a demand equivalent to B7 (7% blend of biodiesel in diesel). The excess of capacity led to high levels of concurrency and predatory strategies on biodiesel auctions, lowering prices to levels economically harmful to the chain. In the same period, soybeans' price reached a very high level, due to its use not only as raw material for fuels but also as food. The conjoint of these factors caused negative effects such as the failure to deliver the volume sold in auctions by some plants. In the midst of this scenario, the government decided to anticipate for July 2008 the increase of the percentage of mixture to 3% (B3), an advance of nearly a year, in order to better balance supply and demand in the biodiesel market.

Rio Grande do Sul State (RS) has an important potential to contribute to the production of biodiesel in Brazil. Considering the year of 2008, Brazil produced 51.784 million liters of biodiesel, of which RS was responsible for 9.647 million liters, corresponding to 18.6% of the total production. Accordingly to IBGE (2008), it represents an annual production of: (i) 3.83 million hectares of soybean; (ii) 19.57 thousand hectares of sunflower; (iii) 21.22 thousand hectares of canola; and (iv) 2.3 thousand hectares of castor. These are the main oils that serve as raw material for the production of biodiesel in the state.

Another important issue is the relation between the production of raw materials for biodiesel and family farming. Family farms, in RS, are central actors in the production chain of biodiesel, for instance they represent 58% of GDP of soybean production in RS (Brasil [39]). The importance that the Brazilian Government attributes to family farms led to the statement of Normative Instruction #01 (Brasil [17]), under which companies in the South Region producing biodiesel should acquire at least 30% of raw materials from local family farms in order to be benefited with a different tax policy, as stated in the Act 11.116/2005. In the case of adoption of this policy, companies could be framed in a social label, which is shown to final consumers in the fuel pumps.

The challenge that is presented now is to identify robust and creative ways to promote sustainability and competitiveness to the actors of this value chain. The construction of actions which can contribute to lever sustainability and competitiveness of the biodiesel production chain in RS demands alignment among actors, which could be obtained by understanding the collective goals and individual mental models (Wind et al. [43]), which is crucial to consolidate a shared and robust view, focused on the common good. In order to do so, tools like modeling and prospective scenario analysis can benefit actors and managers to establish better understanding of the ties of this system and its relationship regarding the biodiesel production chain.

This paper presents the results of a prospective analytical study performed by a research group of the Masters Program on Production and Systems Engineering of UNISINOS and Instituto Euvaldo Lodi (IEL-RS). The aim of the research was to model and better comprehend the relationships among the actors of the biodiesel production chain in RS and to analyze possible future scenarios, considering the year of 2020 as horizon. Based on this analysis, the research tried to contribute to the community by promoting a critical reflection on issues relevant to the theme of biodiesel production.

The remainder of this paper is presented as follows: the next session presents some background elements regarding the biodiesel production chain and its actors. Then, some elements related to the materials and methods used to perform this research are presented. Based on these elements, the results of the research are presented and discussed. Finally, some conclusions are drawn.

2. Background

2.1. Agroindustrial production chains

An Agroindustrial Production Chain (APC) is a production chain related to value generation from agricultural raw materials which are transformed by industrial intervention. As proposed by Batalha and Silva *apud* Batalha [4], an APC can be divided into three segments, as follows:

- Marketing: represents companies that are in contact with the final customer of the production chain and that enable the consumption and trade of final products (supermarkets, grocery stores, restaurants, etc.), including companies responsible only for logistics of distribution;

- Industrialization: represents the firms responsible for processing raw materials into final products for the consumer. The consumer can be a family unit or other agribusiness; and
- Production of raw materials: representing the firms that supply raw materials for other companies to produce final product (agriculture, livestock, fishing, farming, etc.).

Based on such authors, one can notice that the use of different approaches to study APCs attempts to address issues such as: distribution, logistics, optimization of processes, strategies, governance, institutional relationship, and several streams. This is so in order to describe and understand the complex dynamics of production chains, both as they relate to trade and competitiveness of firms, as well as regarding the relationship between the various chains that intersect, compete and are supported by each other. It is important that the coordination mechanisms are sufficiently robust to be able to integrate all stakeholders towards add value and eliminate losses. The central idea is that, at each step, the provisions of intermediary services contribute to the final outcome of the operation (Dornier et al. [33]). The process of integration of actors of the production chain needs a strategic alignment. To define ways to facilitate the conciliation of corporate strategies and the chain strategy is equivalent to prepare a strategic plan for the entire chain (Batalha and Silva *apud* Batalha [4]), since the main goal is to harmonize the strategic intentions of each participant in the chain, plan and facilitate actions which enable the formation of strategic alliances for success. Such alliances are associated with the implementation of cooperation agreements along the Agroindustrial Chain, and, in addition, preserving individual spaces within the chain.

2.2. A view of the biodiesel chain on RS

In a production chain several actors interact continuously on several ways and many different variables need to be considered in order to understand the global effects perceived on the performance of the chain. Actors can act in favor of each other in some aspects and, simultaneously, act in an opposite way in other ones. Situations of impasse or conflict are typically the result of partial visions of reality. Thus, understanding the reasons why different actors take certain courses of action enables the search for solutions or consensus, in order to eliminate or reduce potential conflicts or deadlocks.

The production chain of biodiesel has a large number of actors who contribute, in a direct or indirect way, for the production of this biofuel. Fig. 1 shows the main actors and their direct relationships, but the multiplicity of relationships between actors in the chain is much greater than that illustrated by Fig. 1.

By understanding which actors take part of the chain, it is possible to strength the critical view on both controllable and uncontrollable processes associated to the biodiesel production. Accordingly to Zonin [44], there is a strong relationship of this chain with the agricultural business chain, regarding the search for raw materials to the production process. This relationship includes several topics, such as: (i) the choice of oilseed crops and the organization of the processes for supply of raw material; (ii) the agricultural production system used; and (iii) the purchase of grain and vegetable oil. Therefore, this part of the production chain is highly dependent on external factors such as: (i) topography, soil and climate factors; (ii) changes in relative prices of raw materials (e.g. raw materials that work as commodities and have prices that

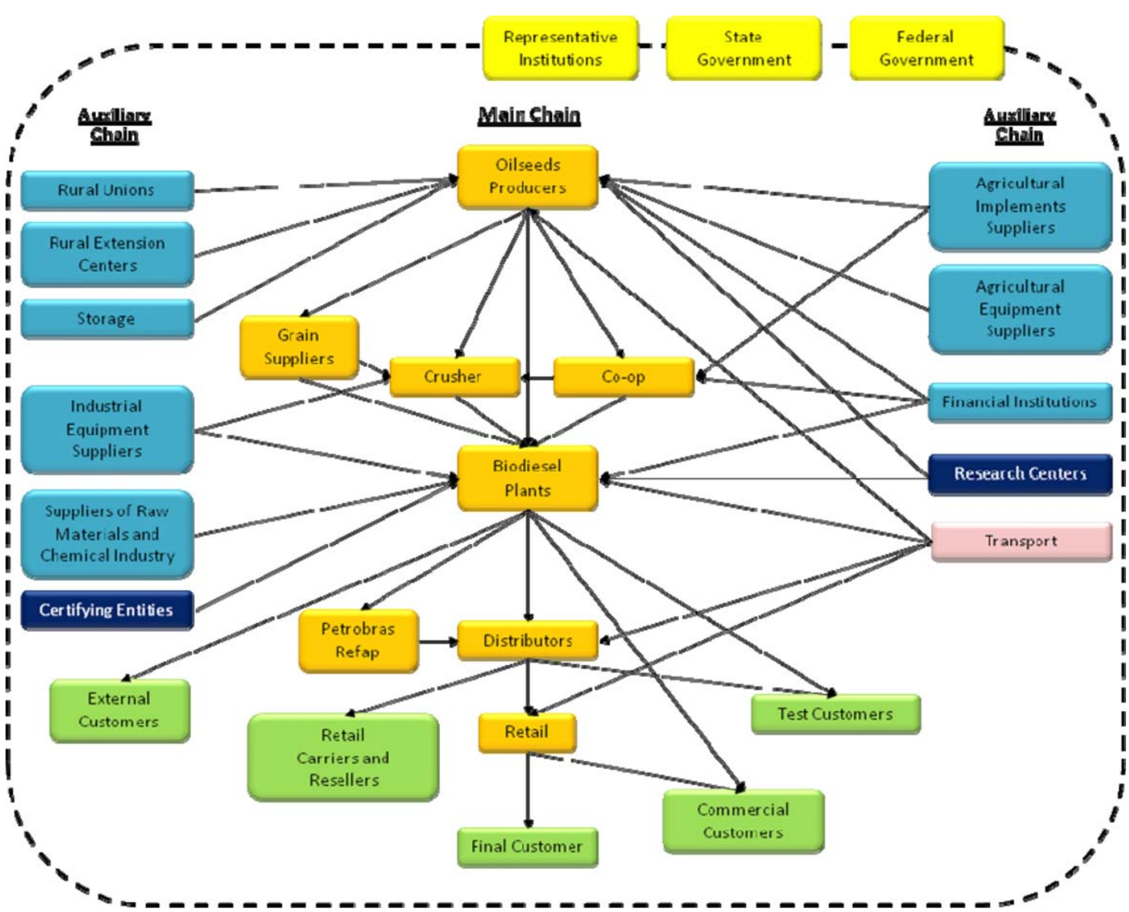

Fig. 1. A simplified view of the biodiesel production chain in RS.

are regulated by the global market). This leads to infer that the associated variables to this relationship tend to be more difficult to control due the variations and uncertainties associated.

On the other hand, departing from the entry of raw material in the biodiesel plant, the factors involved in the production of biodiesel tend to be more controllable, being strongly associated to production processes (Zonin [44]; Kuiawinski [37]), such as receiving, storage, processing and final distribution. So the variables associated to these processes are subject to minor changes and risks.

To understand how this system evolves it is necessary to identify the forces which lead its actors to interact. These forces are linked to some key factors which define the future behavior of the system. In the context under analysis, the key factors identified were: (i) public policies; (ii) price and diversification of raw materials; (iii) family agriculture; (iv) alignment and sharing of information; and (v) demand of biodiesel.

2.2.1. Public policies

FG launched the PNPB as an implementation of the strategy for developing biofuels as an alternative to replace fossil fuels (ANP [2]). More broadly, by creating the law 11.116/2005, the FG linked the biofuel production to an attempt of reducing poverty in rural areas, creating the Social Fuel Label Program (Brasil [38]), a mechanism to ensure the participation of family farming in the production chain of biodiesel.

Accordingly to Abramovay and Magalhães [1], the current policy which supports the PNPB is, in practice, more than a case of contractual integration, typical of the methods of Supply Chain, which are involved in the formation of a unique pattern for the functioning of the market and its governance. PNPB represents a market that begins to form from a government intervention that encourages the participation of farmers in a specific production matrix and, at the same time, wishes to encourage the use of raw materials little used until that time (Abramovay and Magalhães [1]).

Regarding the development of the market, the FG created an institutional apparatus to coordinate the demand, marketing, distribution, prices and quality of biodiesel. Several acts from National Petroleum Agency, from 1999 to the present days, establish criteria to produce, evaluate quality, distribute, blend and commercialize biodiesel (ANP [2]; Brasil [5–29]). They also establish the procedures to perform auctions for quotas of production of biodiesel and the roles of several actors regarding the commercial aspects of the production chain (Zonin [44]).

The absence of private initiative in the governance system of PNPB brings some vulnerability to the system. This can lead to asymmetries of information and little strategic alignment among economic agents and public policy. As examples of consequences, one can notice situations of supply excesses or shortage of biodiesel, and little success in introducing new oilseeds in the production chain.

Moreover, the role of the State Government in define the agroclimatic zoning is considered fundamental at all stages of the development of production chains and raw materials. Also, it should be noted that the State has an effective role in the promotion of the exploration of a new production matrix, with emphasis on other cultures beyond the soybean crop, which is predominant (Zonin [44]).

2.2.2. Price and diversification of raw materials

In the composition of the production costs of biodiesel, the raw material represents more than 85% of the total cost (Zonin [44]), and in Brazil soybean is the most used raw material for the production of biodiesel. This raw material has two components worthy of attention (Abramovay and Magalhães [1]):

- its price is determined by the global demand for food. So, local actions to influence price are poorly effective; and
- as an edible oil, soybean oil is incorporated into the international conflict of food security.

Because of these aspects, there is a search for non-edible raw materials, economically viable for the production of biodiesel and which do not compete with the production of soybeans. Ideally this raw material should not interact with the production of food (Brasil [30]). Initiatives for diversification of cultures would have a very significant contribution if they provide options for growing on areas where the traditional commodities (soybeans, wheat, corn, etc.) have low economic value and poor production performance. In areas where cultures such as soybean are highly productive, it seems to be hard to implement other cultures without losses to the farmer's income.

Regarding the commercial matrices for soybean, sunflower and canola, it can be inferred that their prices tend to react as commodities, and the trend is of elevation. As for the castor bean, analysis points that there is a low use of its oil to produce biodiesel and this tendency should keep in short and medium term for technological reasons, due to processing and adjustments required in transesterification plants. At the same time, it is relevant to consider that besides the growth of the oil-chemical industry (which absorbs the castor oil), it is not comparable to the competitiveness and size levels of food industry, which is able to absorb more aggressively the increase of production of raw materials, such as sunflower and canola, for example (Zonin [44]).

2.2.3. Family agriculture

Due to the structural public policy of PNPB, family farming is seen as key in the biodiesel production chain. The success of the program is linked to greater social integration of rural producers. This guideline of PNPB is particularly important in RS, where family farming is essential to the economy of the state (Brasil [38]).

The expertise developed through decades in the handling of soybean and the easiness of its marketing, consolidated its privileged position among small farmers. According to IBGE [36], family farms, in 2006, produced approximately 50% of all soybeans of RS. This performance is due to the degree of technical background used, the use of equipments at the properties, and the organization and cooperative associations, in order to produce as one could conceive as scale production. This fact complicates the introduction of new cultivars and production systems.

The path to improve the income and social inclusion of family farming seems to be linked to the transfer of technology and knowledge to the farmers, with the implementation of production systems for diversification and increase in food production and raw energy. Holanda [35] estimates that, among the social benefits of PNPB, every 1% of replacement of diesel with biodiesel produced with materials from family farming, has the potential to generate 45 thousand jobs in the field, with an average annual income of approximately R$ 4900.00 per job. In a comparison regarding job creation between business and family farming, Holanda [35] notes that corporative agriculture, on average, employs a worker for 100 ha, while family farming has a ratio of 10 ha per worker. These data reinforce the importance of prioritizing family farming in the production of biodiesel as an element of social inclusion.

2.2.4. Alignment and sharing of information

The production chain of biodiesel is complex and some actors are also part of the other production chains, particularly poultry and pigs. As a chain in development, with a system of information sharing and relationships still fragile, the effects of difficulties on establishing links between actors can be aggravated, compromising the performance of the entire chain.

One possible way to produce alignment and sharing of information is to induce the formation of networks. Casarotto Filho and Pires [32] suggest the following main objectives that lead to the creation of networks: (i) combine skills and use know-how of other companies; (ii) share the burden to search for technology, development and sharing knowledge; (iii) share risks and costs of exploring new opportunities, performing experience together; (iv) offer a superior quality and more varied product line; (v) have a higher pressure in the market, increasing the competitive strength for the benefit of the client; (vi) share resources, with emphasis on the ones being underutilized; (vii) strengthening the power of bargaining, and (viii) have more power to act in international markets.

The performance of organizations as a network has some goals: (i) reduce the vulnerability of firms to new competitors; (ii) increase the capacity and speed of absorption of new techniques and management; (iii) create conditions conducive to the innovation process (by dividing costs associated with applied research and technology); and (iv) increase the power of bargain of firms in the chains in which they are inserted (Verschoore Filho [42]).

The lack of a governance system for the chain in RS, in addition to the lack of information and poor alignment of the actors, reduces the probabilities of success in the implementation of public policies.

2.2.5. Demand of biodiesel

The national demand for biodiesel is currently set by government policies which are implemented through legal mechanisms to determine the requirement and the volume of the mixture (ANP [2]). This dynamics of intervention is necessary to promote the adjustment of supply and demand, since this is a market that currently does not operate freely. The emergence of demand without government intervention could be an important change in the relationship between the prices of diesel and biodiesel. The adjust of this imbalance will only be possible in a scenario of reduction of biodiesel production costs and/or of increase in the price of diesel (Zonin [44]; Batalha and Silva *apud* Batalha [4]).

The key factors briefly presented here were used as focus of discussion in the research. They were also important to the development of the systems dynamics model created to achieve the objectives of the research.

3. Material and methods

3.1. System dynamics and systems thinking

System dynamics is a methodology to represent the real world. It can embrace the complexity, nonlinearity, and feedback loop structures that are inherent in social and physical systems (Forrester [34]). By system one can understand a perceived whole, whose elements remain continuously affecting each other over time, and work for a common purpose. According to Capra [31], the systemic ideas appear as recurring theme in science through holistic concepts as opposed to mechanistic conceptions. What system dynamics attempts to do is to understand the basic structure of a system, and thus understand the behaviors it can produce. Many of these systems and problems which are analyzed can be built as models on a computer. System dynamics takes advantage of the fact that a computer model can be of much greater complexity and carry out more simultaneous calculations than can the mental model of the human mind (Forrester [34]).

Systems thinking is a process of constructing maps and models that involves the analysis of the interrelationship of the elements of the system (in cycles of feedback instead of linear chains of cause-and-effect) and analysis of the systems' dynamic processes over time (rather than taking snapshots of specific moments). The methodology for the application of systems thinking is based on concepts of dynamic systems, especially, closed cycles and feedback. Considering inter-relationships and feedback cycles, the systemic thinking allows not only the analysis of events but also of patterns of behavior and structures of the system.

If the model is relevant and persuasive, and if understanding about the problem has been sufficient, then analysis of alternatives can progress smoothly. Even so, implementation may take a very long time. Old policies must be rooted out. New policies will require creation of new information sources and training. Evaluation of the policy changes comes after implementation. As well as determining the model adequacy, evaluation has no clear procedures, nor can one expect a conclusive outcome. The evaluation may even rest on results other than those for which the project was undertaken. Evaluation will remain subjective, and the weight of evidence will accumulate as system dynamics becomes the common thread through an accumulating sequence of successes (Forrester [34]).

One of the benefits of the adoption of the systemic approach is the understanding of different levels of reality. This understanding is achieved by deepening the perception, on a structured way, of four levels of reality acting simultaneously: events, patterns of behavior, systemic structures and mental models (Andrade et al. [3]):

- Level of events: events occur and are perceived by those involved. In general, actions based on this perception tend to take things reactively and are the most common type of action.
- Level of patterns of behavior: for a perception beyond the level of events, one must examine the long-term trends and assess their implications. Charts and historical data can be used to evaluate the behavior of variables over time and look for evidence that might indicate their future behavior. In this case, actions take a responsive orientation, as they are indicative that the actors can respond to trends of change.
- Level of systemic structures: the third level refers to understanding the structural situation. It indicates the relevant patterns of behavior, seeking to explain how the elements are influencing each other. At this level, the correlations between variables and their implications over time (e.g. delayed effects) are considered. This level of analysis is the richest and allows the best intervention in terms of leverage for change, since the structure generates behavior, and by changing the structure, one can generate different patterns of behavior.
- Level of mental models: mental models are deeply rooted ideas, generalizations, or images that influence how to face the world and the attitudes of people. Assuming that structure creates behavior and that perception of reality creates the structure, one can infer that this level influences the others. So, the mental models of actors influence their ways of generating systemic structures and understanding reality. By questioning mental models, one enables the formulation of innovative and creative solutions, from new readings of reality.

The systemic approach enables the analysis of different situations from a broader and depth perspective, allowing the construction of robust solutions, structured and leveraged for sustainable results.

3.2. Systems thinking and scenario planning

This study followed a methodology based on the standard developed by Andrade, Seleme and Moutinho (*apud* Andrade et al.

[3]). The method merges meetings of short term with remote tasks for the participants. Each meeting generates a small collection of activities of data analysis or reflection, to be held by the participants as a preparation for the following meeting. The method looks for a shared understanding of the problem under analysis, through dialogue.

The lead time of project was approximately of five months. A group of specialists participated of the meetings. Also, two presentations for a broader group of specialists were performed, in order to establish external validation of the findings. For this project, the method was developed in 15 weekly meetings, as shown below:

3.2.1. First step: definition of the work team

Since one of the key elements of the method is forming a shared understanding of a problem, the selection of the team members must be carefully performed. It is suggested forming a multidisciplinary team to allow different views of the context of the system to be analyzed. At the first meeting the team is presented to the assumptions and language of representation used for the development of modeling of dynamic systems.

3.2.2. Second step: definition of the problem and recovery of historical events

The purpose of this step is to clearly define the complex situation of interest. This requires clarifying the situation considered important for the team. This step is usually performed in one meeting, in which the team intends to comprehend the first level of reality, to assimilate the relevant events relating to the situation over the period considered. The importance of this step is bringing forth the history and the stories behind the problem under analysis.

From the list of events reported, it is necessary to identify factors that may be listed as keys to understanding the situation of interest. Everything that contributes to an outcome on the situation and is subject to variations should be noted.

3.2.3. Third step: identification of patterns of behavior

This step is dedicated to identifying the past behavior and future trends of key factors. The main goal is to penetrate the level of behavior patterns. Historical data are used, but also can be used qualitative patterns, in order to support the team's thinking and learning, and recognizing factors which are inter-related (matching behaviors).

3.2.4. Fourth step: construction of a systemic map by using correlations

This step was developed in two meetings. The main goal was to identify causal relationships between factors from the comparison of curves, preliminary assumptions and intuitions about the reciprocal influences. The goal is to uncover the systemic structures that determine the patterns of behavior of elements of reality. In order to represent these relationships, the language presented in Fig. 2 was used.

3.2.5. Fifth step: complementing the systemic map by using archetypes

Archetypes are systemic structures that can be found in different situations. Archetypes are also a natural vehicle for clarifying and testing mental models. By identifying an archetype it is possible to identify new elements that are generally present in its structure, but were not included previously (Senge [41]). This step was performed in three meetings, due the complexity of the biodiesel production chain.

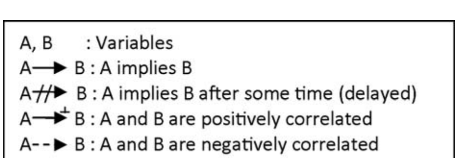

Fig. 2. Language to construct systemic maps.

3.2.6. Sixth step: identification of mental models

The objective of this step is to identify the mental models, or raise the beliefs or assumptions that the actors involved in the situation maintain and that influence their behavior, creating structures in the real world. To enrich the framework, is necessary to transform the mental models into elements of the systemic structure.

3.2.7. Seventh step: identification of driving forces and creation of scenarios for analysis

Driving forces act structurally in reality and impact on decisions taken. In general, such forces are external to the system. Understanding the driving forces makes possible the construction of scenarios of analysis. The main idea is not to identify the most probable scenario, but understand how actors interact in order to generate robust action plans.

3.2.8. Eighth step: analysis of scenarios

The goal of this step is identifying the pattern of behavior of the system in response to change in key variables. Changes in key variables are set based on the description of scenarios to be evaluated. Each scenario is detailed in the form of a narrative, and actors, driving forces and critical uncertainties are identified. Each scenario is, then, analyzed by the specialists in order to identify actions to prepare for different futures, aiming more robust decision-making. For this research, this step was developed in three meetings.

3.2.9. Ninth step: establishment of a robust action plan

Redesign the system means to plan changes in its structure, in order to achieve desired results, considering the systemic consequences of these changes. This is usually done by identifying a plan of actions which add new elements, new links, or broke links that produce undesirable effects to the systemic structure of the problem. The fundamental thought of the system is the 'Principle of Leverage', that is, find out where the actions and structural changes can bring significant and lasting results. According to the principles of systemic thinking, in most cases, the best results do not come from measures on a large scale, but small and focused actions. Also, this plan is based on a comparative manner, aiming to identify scenario-independent actions which can be established to promote the positive effects and protect from negative effects of different scenarios. For this research, this step was developed in two meetings and the results were presented to two different groups of specialists on the theme.

4. Presentation of results, analysis and discussion

As a first result of the application of the method discussed before, Fig. 3 presents the systemic map developed through the study. Several variables were considered, regarding the key factors and the actors of the biodiesel production chain, previously presented at the background section. The analysis of the systemic structure allowed identifying the effects of many variables on sustainability of the actors, social inclusion of small farmers and the necessity of articulation as a mechanism for ensuring demand and support for research and development. These elements were important to the analysis and definition of the scenarios, which will be presented next.

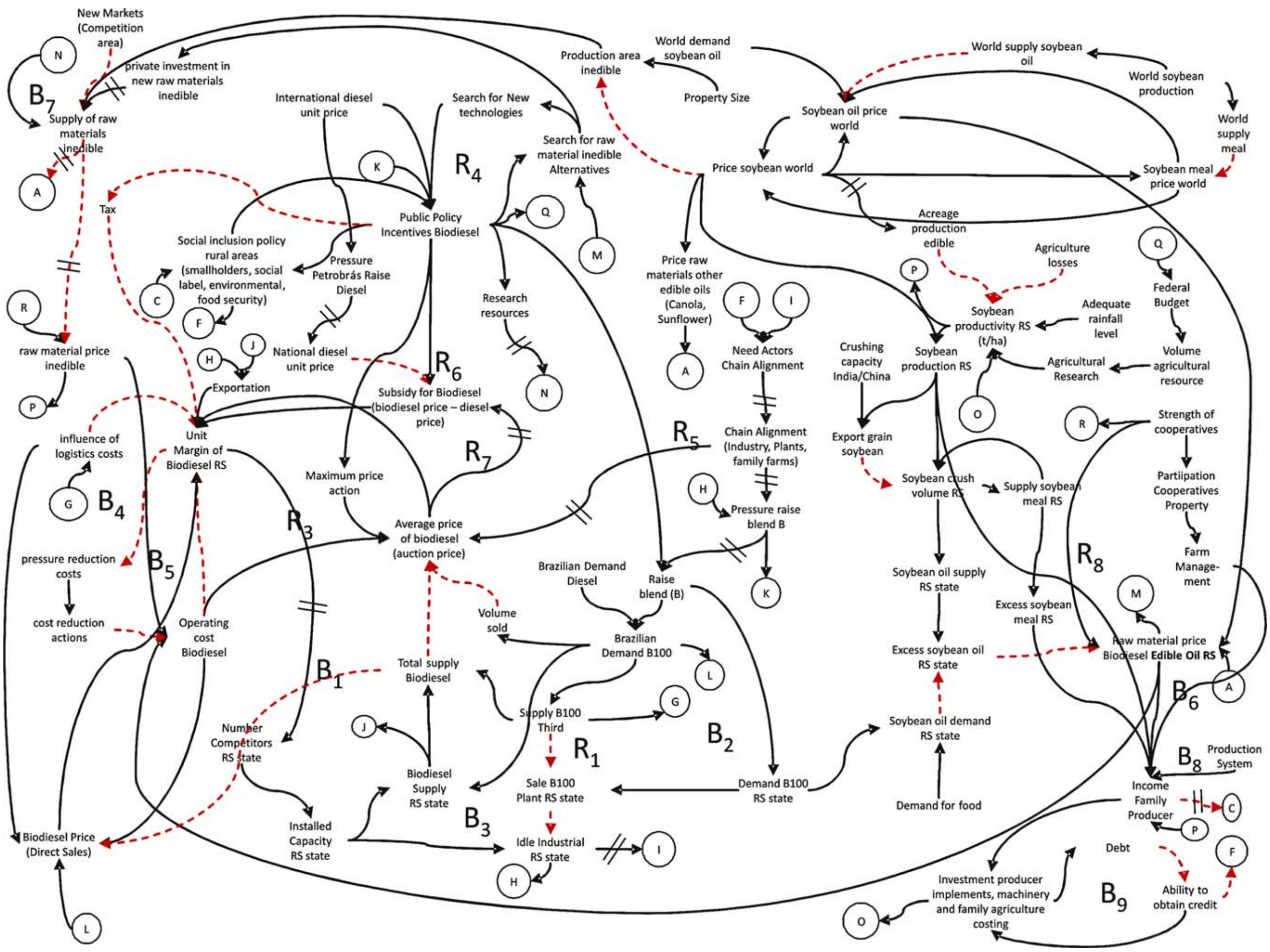

Fig. 3. The systemic map developed.

4.1. Analysis of scenarios

The scenarios to be analyzed were created by a rich narrative approach (Schwartz [40]; Senge [41]; Andrade et al. [3]) which aims to create an in deep discussion about future realities, faced when uncontrollable driving forces (so called 'critical uncertainties') assume predefined levels. The main idea is to understand how the feedback loops of the systemic map will respond to such external forces, in order to propose robust actions.

The scenarios developed for analysis were based on two axes considered key to the sustainability and competitiveness of biodiesel chain of RS: "Effectiveness of public policies for the biodiesel chain in RS" and "Price of raw materials for production of biodiesel". As states the methodological approach used, for each axis were assigned two extreme levels: "effective policies" or "ineffective policies", "high price" or "low price". In order to facilitate the interpretation and reference, each scenario was baptized with a name – a Keywords – which allows summarizing its essence. Fig. 4 shows the generated scenarios; which will be briefly presented; as narrated by the team; in the sequence.

4.1.1. Scenario 1: competitive challenge

The name "Competitive Challenge" indicates a scenario in which raw materials are obtained at relatively low costs but there is inefficiency of public policies with regard to the chain of biodiesel in RS. In this scenario, the minimum percentage of biodiesel in the mixture of diesel is low, around 3%. The price of biodiesel is similar to the one of diesel. A raw material economically attractive is available, but eventually divorced from traditional agricultural production. The soybean is still the most attractive in the planting decisions of producers in traditional agricultural areas, as these have already mastered the technology, they have guaranteed prices and markets. Prices of agricultural raw materials for food remain oscillating with a trend of elevation in the international market. The search for agricultural non-edible raw materials presents results not yet competitive. Thus, the introduction of new cultivars faces barriers. The dissociation between the production of agricultural raw materials and biodiesel production weakens the pillars of PNPB. The low capacity to achieve the objectives of the guideline for social inclusion of family farms through the program reduces the FG's commitment to continue the application of resources in it. As a result of this context, there is high dependence on technology for the development of new materials, which are obtained by the development of R&D by initiative of the industry or by purchasing abroad. Support for plants with insufficient equity is compromised by the high cost of access to technology, leading to the concentration of production in large corporations. The domestic market offers limited demand which generates low results, making the external market strategic important.

In this scenario, the structure of players who currently form the chain is not sustainable. The family agriculture loses importance as the use of non-agricultural raw materials to produce biodiesel expands. However, other actors, related to the production of second generation biodiesel, are incorporated to the chain, as might be the case for producers of seaweed, for example. The competition between the plants increases, restricting the market

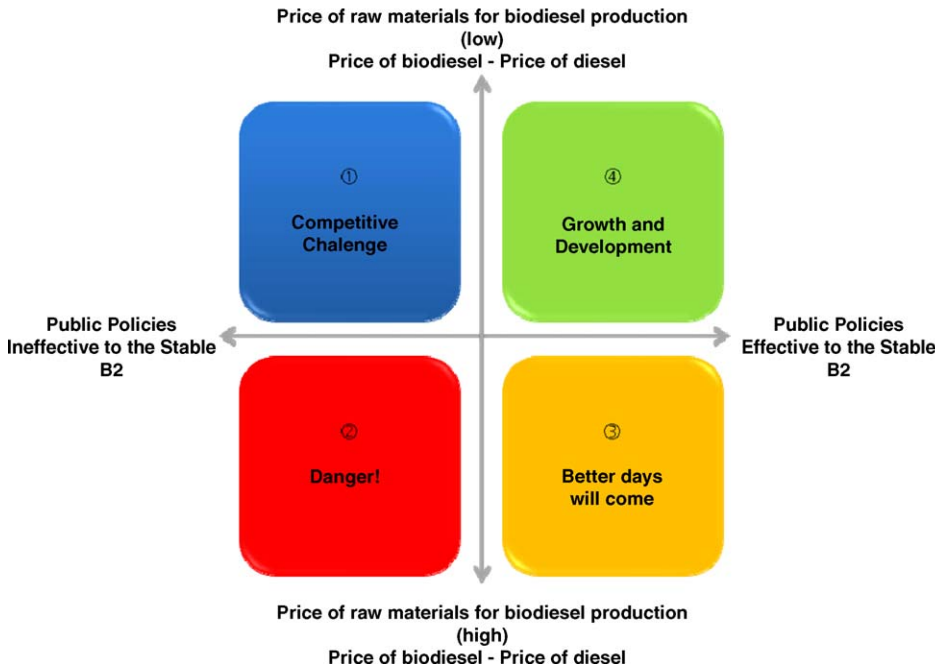

Fig. 4. Scenarios for the problem under analysis.

to the more competitive ones. The bargaining power and the flow of the production of biodiesel (e.g. the logistics cost) from each plant is a determining factor for the competitive positioning. In this context, competitiveness and sustainability depend on actions to promote structural changes in the availability of resources and efforts of private enterprises, with little relevance of public policies.

4.1.2. Scenario 2: Danger!

In the scenario baptized as "Danger!" there is no alignment of the actors in the biodiesel chain: there are low-interaction and involvement between players, leading to the development of silos of information. Consequently, the available information is poor and resulting analyses are incomplete, favoring that actions implemented by the public sector and private agents are ineffective and jeopardizing plans for joint actions. PNPB brings few results and, therefore, have low credibility. It does not contribute to the generation of income in family farming. The strategies used to monitor and regulate the biodiesel chain fail and the results of scientific research and technology has little expression in terms of economic viability. Access to foreign markets is compromised due to the uncompetitive price of biodiesel and the lack of social and food safety labels—which could generate a competitive differential for Brazilian biodiesel. Companies economically less competitive leave the market, and the production is dominated by large corporations.

The consequences on the competitiveness and sustainability are severe. The high price of raw material mitigates the competitiveness of the chain and increases the need for governmental actions such as increasing the percentage of the mixture, without which the chain will have difficulty to continue. Medium businesses have difficulty to compete with large corporations, which virtually dominate the market. The agricultural sector is unable to improve their productivity in oilseeds and, consequently, the costs of agricultural raw materials are high, undermining the sustainability of the biodiesel chain. The family farm has difficulties to be inserted in the chain, which prevents social initiatives for certification of biodiesel, blocking access to foreign markets and reducing the FG's interest in this chain.

4.1.3. Scenario 3: better days will come

In the scenario, baptized as "Better Days Will Come", the production cost of biodiesel remains high, given the high price of raw materials. However, the demand for biodiesel is high and it ensures economic return to the production chain, even with small profit margins. The FG is strengthened by the positive results of PNPB, mainly for greater social inclusion of family farming, which participates in the chain. The increase in the producer's family income is obtained through the use of production systems, which allow the systematic planting of food and energy crops. New alternatives for agricultural raw materials arise, but soybean still is preferred over the others. There is no abundant supply of non-edible raw material for the production of biodiesel, requiring the use of edible raw materials. The conflict "food vs. biofuel" may persist. Society understands the environmental and social gains associated with biodiesel, and is receptive to use it, even if it has a higher price. The FG regulates biodiesel to be viable on the market because its price is still higher than diesel. The supervision of the chain is effective, promoting the competitiveness of plants, and ensuring the quality of biodiesel. The new frontiers of business abroad are subject to the implementation of social and food safety labels.

The actors in the chain interact and commit themselves to joint actions. Thus, the generation and sharing of information and knowledge enable more rational decision making, even for new entrants and for the rehabilitation of idle plants. The possibility of new entrants is subject to opportunities for gain and the regulation established by the FG. The sustainability of the chain is dependent on government policies. The farmers have more opportunities to diversify production and access to new markets, so they expand their incomes, what promotes social inclusion. Competition with other states threatens the competitiveness of the chain in RS. Taxes and logistical costs need more attention. Another challenge for competitiveness is that the margin of the plants depends on the reduction of costs due to scale production and marketing subsidies to the price of biodiesel. Finding new markets for co-products becomes important for the sustainability of the chain. Coordinated actions of the actors create a cycle of reinforcement between alignment and performance: alignment

maximizes the social and economic outcomes generated by the biodiesel, and the perception of success in obtaining these results strengths the alignment of actors.

4.1.4. Scenario 4: growth and development

In the scenario "Growth and Development" PNPB meets the expectations and consolidates the biodiesel economic sector, enabling the actors in the chain to have profit and capacity of investment. Society realizes the social, economic and environmental aspects of biodiesel. The family farm is part of the chain. There is alignment between the actors, and information and knowledge are generated and shared among the actors of the chain leading to more rational decisions, even for new entrants and for the rehabilitation of idle plants. FG regulates the chain and the surveillance is effective. The quality of biodiesel achieves the standard of benchmark. The social and food security labels are validated and perceived as means of achieving the external market. The family farming is leveraged with technology, generating income through the use of production systems. The industry shows no idleness and biodiesel market is attractive to new entrants. However, the entry is subject to opportunities for gain and the regulation established by the FG. The price of biodiesel is approaching the one of diesel, and could even be lower, due to the low cost of production and distribution of biodiesel.

There is sustainability and the chain is competitive. The technology for the chain progresses and improves the professionalism in all the ties. The industries are able to maintain themselves on domestic and international markets. Operating margins allow performing investments in R&D. The family farm participates in the chain with no reduction of food production, earning income with social inclusion. PNPB and social labels are strengthened, giving consistency to the social and food security. The logistics cost is more important for the chain in RS, because of the increasing number of competitors in other states. The accumulation of glycerol makes it important to prospect new uses and markets for this co-product and others.

4.2. A proposal for an action plan

Comparative analysis of scenarios aims to identify structuring and leveraging actions. Structuring actions since the scenarios are designed based on the systemic structure of relationships between actors and variables associated with the context of biodiesel in RS. The actions are presented as leveraging actions, since the method seeks to find actions which work on the key elements of this structure. Based on such analysis, some macro-actions were suggested by the team, to promote dialogue between stakeholders to achieve sustainability and competitiveness for the production of biodiesel in RS. In the exercise of formulating macro-actions this work tries to establish guiding strategies. These strategies, as shown in Table 1, are presented as suggestions for discussion.

Table 1
Guiding strategies to promote the biodiesel production chain in RS.

Strategies
1. Create development plans for stimulating agricultural production systems, in accordance with the strengths of each region
2. Invest in diversification of products of the plant, adding value and quality to co-products
3. Investing in corporate R&D to lower costs, reduce waste and increase productivity
4. Invest in logistics management and reduction of logistics costs
5. Access the external market, seeking more competitive pricing and using certifications—labels regarding environmental, social and food security
6. Invest in shares to the opening of markets abroad
7. Strengthen the interaction and strategic alignment between the research centers and the production links

Table 2
Actions to promote competitiveness and sustainability of the biodiesel production chain in RS.

	Action
Short term	A1. Create forums and information systems to promote alignment and shared vision among the chain.
	A2. Promote alignment with government ministries, agencies for technology transfer and private initiative for implementing projects for development of co-products and of the chain of biodiesel.
	A3. Promote a study for supply chain and distribution optimization.
	A4. Solidify contracts between farmers and biodiesel plants.
	A5. Identify foreign target markets for biodiesel and co-products.
	A6. Promote alignment between actors of the chain and research centers.
	A7. Raise funds to promote research projects targeted to biodiesel.
Medium term	A8. Find resources and undertake the mapping of agroclimatic research and economic feasibility for alternatives to soybean oil, taking into account the skills of each region of the state.
	A9. Stimulate change in the governance of PNPB, with greater participation of private initiative.
	A10. Conjoint actions to implement projects to reduce agricultural losses.
	A11. Propose the establishment of internationally recognized labels for food security and social inclusion related to biodiesel.
	A12. Stimulate the creation of networks of cooperation, learning groups, research networks, etc. to strengthen the mechanisms for innovation and generation and dissemination of knowledge among the chain.

Given the complexity of the chain and the number of different actors involved, a large number of actions were proposed by the team of specialists in order to implement the previously presented guiding strategies, summing up 27 actions. Twelve were selected as priority, accordingly to the perception of their potential benefits, separated in short term and medium term actions, as presented in Table 2.

The implementation of the actions listed at Table 2 requires a collaborative effort from governmental and class organizations. Actions A1, A2, A6, A8 and A12 are being reinforced by Brazilian Government, and Rio Grande do Sul Government, by means of the so called Structuring Projects, aiming to promote forums for discussion and development of knowledge (strategic and technical) about the biodiesel chain. Actions A6 and A7 were currently supported by strategic governmental funds, but there is a necessity of raising other initiatives, from industries' associations or non-governmental representatives. The same occurs with actions A3, A4 and A10, which are of greater interest of the industrial actors of this value chain. Finally, actions A5, A9 and A11 are currently managed by Brazilian Ministries, but require coordinated actions from the actors of the biodiesel chain, in order to ensure future sustainability.

Coordination of actors and knowledge sharing are key issues to promote sustainability and competitiveness for biodiesel. Some movements are observed, from this coordination, such as the anticipation, from Federal Government, of the mixture B4 in relation to the original schedule for biodiesel use in Brazil.

5. Conclusions

The theme of biodiesel production is part of a discussion of national and regional strategic interest, with international

repercussions. The agricultural potential of the RS is, at the same time, an opportunity and a challenge for the production of biodiesel. This study shows evidence that the alignment of actors in the chain can leverage actions to sustainability and competitiveness in the coming years. It also identifies dependence on public policies, especially federal ones, for the development of the production chain of biodiesel in RS, in the short and medium term.

PNPB was designed taking into account a social concern, which, at least in theory, allows the participation of small farmers in the supply chain of biodiesel, both in scale agriculture (as networks) and in family farming. However, from the economic and financial point of view, there are objective difficulties for the structuring of the production of agricultural raw materials from family farms.

The research also points out the need of considering the dependency of raw materials as a central element in enabling the economic production of biodiesel in RS. The dependency of commodities markets for defining prices of raw materials, mainly concentrated on soybeans and the inadequate development of new raw materials in scale to meet demand, promote difficulties on establishing a more stable basis for biodiesel production. Still, it is suggested to consider a comprehensive and systemic perspective of the use of agricultural production systems to supply energy and food industries.

This study, although qualitative, was based on quantitative data and on the opinion of specialists. Despite quantitative studies can present different or more refined evidences, this study aimed to contribute from a strategic point of view, by presenting a list of actions in order to promote the attractive elements of the systemic structure of biodiesel production chain and also to protect it from the undesirable elements associated to the different analyzed scenarios. So, without the presumption of being definitive, this study aimed to discuss the need of actions for mutual benefit to the members of this production chain as well as to the society. On the other hand, it seeks to contribute to the dialogue between the various ties and stakeholders of the biofuels production chain in order to share information and to build a common vision which could ensure healthy, sustainable and competitive relationships, now and in the future, not only favoring members of this chain, but also society and Brazil.

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